Journal of Cultural Heritage 16 (2015) 912–917

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Case study

Acoustics as a cultural heritage: The case of Orthodox churches and of the "Russian church" in Bari

Luigi Elicio , Francesco Martellotta*

Dipartimento di Scienze dell'Ingegneria Civile e dell'Architettura – Politecnico di Bari, Via Orabona 4, 70125 Bari, Italy

ARTICLE INFO

Article history:
Received 17 December 2014
Accepted 2 February 2015
Available online 26 February 2015

Keywords:
Acoustics
Orthodox churches
Architecture
Liturgy
Reverberation time

ABSTRACT

Architecture of Orthodox churches changed very little in its history as a consequence of the strict adherence of liturgy and its related aspects, to the original canons. This has important implications on the acoustics that characterizes such places which is therefore very specific. The paper starts by considering the case of the Orthodox church of San Nicola (also known as "Russian church") in Bari where an acoustic survey was carried out. Innovative measurement tools like microphone arrays were used, allowing the identification of direction of arrival of sound reflections and, consequently, the architectural elements that play a major role on the acoustics. Then, the results of a detailed literature research are used to put the specific case study into a broader context including a large number of Orthodox churches. Results point out the existence of a very specific relationship between acoustics and architecture, supporting the idea that the first must be considered as a cultural heritage as important as the latter.

1. Research aims

The paper analyzes the case of the Orthodox Church of San Nicola in Bari, outlining its acoustic characteristics and their relationship with architecture. Use of innovative visualization tools allowed the identification of architectural elements, like the apse, that play an important role on the acoustics. Finally, the comparison with literature data of a large sample of Orthodox churches allowed to put the church in a broader context. In particular, the analysis pointed out a marked relationship between acoustics and architectural features (geometry and materials) that stems from the changelessness of Orthodox liturgy and its related aspects. This supports the idea that acoustics must be considered a cultural heritage (although "intangible"), strictly related to the building itself.

2. Introduction

Acoustics is an important feature of several cultural heritage buildings. For theatres, in particular, the idea that the acoustics is by itself a "cultural heritage" began to spread at the end of the last century, when two important opera houses in Italy were destroyed by fire [1]. Since then the idea gained considerable attention from the scientific community leading to the definition of guidelines to correctly measure the acoustical properties of such spaces [2]. In addition, the same concept was extended to other buildings, like worship places [3], in which sound propagation represents one of the most important aspects. Catholic churches, in particular, experienced significant changes in acoustical needs during their history, in relation to variations in liturgy [4]. Conversely, Orthodox churches experienced almost no change in their liturgy and limited variations in their layout, suggesting an even more important relationship between the building (the "tangible" cultural heritage) and its acoustics (meant as "intangible" cultural heritage [5–7]). As a further element supporting this strong relationship, the liturgy is almost entirely sung and the repertoire is made of traditional Byzantine Chants showing very specific acoustic features [8]. In addition, sound sources occupy given positions, with the clergy moving from the sanctuary to the nave, which are separated by the iconostasis, and vice versa depending on the part of the celebration.

From the architectural point of view, Orthodox churches are usually based on a central plan typology, enriched by spaces specifically functional to liturgy (named *prothesis* and *diaconicon*) and located at the side of the altar. The central plan is fitted to the liturgical needs, as it preserves the central role of the altar while ensuring enough space for the religious celebrations taking place around it. From a symbolic point of view, the most representative and widespread plan shape was the Greek cross. However, the *quincuncial* plan variation, in which the cross is in a square, and defines four additional sub-volumes located at the corners (usually

* Corresponding author. Tel.: +39 080 5963631.
E-mail address: francesco.martellotta@poliba.it (F. Martellotta).

http://dx.doi.org/10.1016/j.culher.2015.02.001
1296-2074/

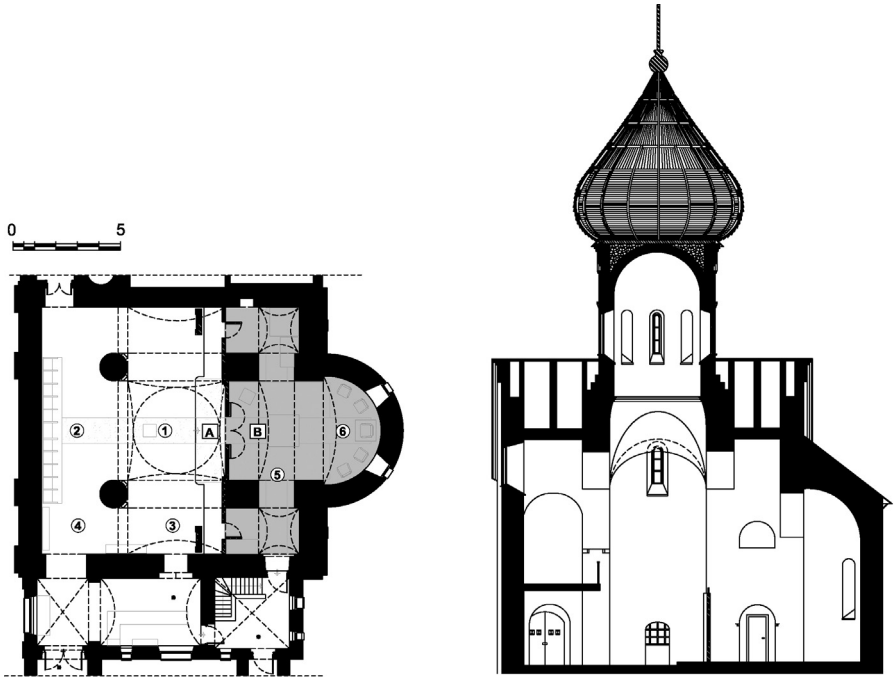

Fig. 1. Plan and cross section of the church with indication of source (A and B) and receiver (1–6) placement. Grey area corresponds to the Sanctuary.

covered with domes), can also be found frequently. When Christian Orthodox religion spread to Russia such models were originally used. However, when Moscow became the most powerful Orthodox city in the world, architecture showed this supremacy by means of bigger churches based on new architectural models, often contrasting with the tradition. The so called "tent-shaped" churches built in the 17th century were among these experiments that, being clearly in contrast with the Byzantine canons, were rapidly dismissed.

In acoustic terms, the above considerations about the similarity of church shapes and materials used suggest a stricter relationship between acoustics and room volume. In fact, the reverberation time, the simplest acoustic parameter, is, according to Sabine's formula, directly proportional to room volume and inversely proportional to room surface times its average absorption coefficient. Thus, if shape (on which the volume-to-surface ratio depends) remains the same, as well as the materials, significant correlations between reverberation and room volume may be expected for Orthodox churches. In order to test such hypotheses, the paper takes advantage of acoustic measurements recently carried out in the Orthodox church of San Nicola (also known as "Russian church") in Bari and, after a detailed bibliographical research, compares them with results already published in the literature.

3. Methods

3.1. Church description

The Orthodox church of San Nicola in Bari is part of a larger building designed by the Russian architect A. V. Ščusev. The church was built between 1913 and 1915 according to the 12th century Novgorod-Pskovian style, and is actually made of two superimposed churches. The lower (mostly used in winter) was dedicated to St. Spyridon and the upper was dedicated to St. Nicholas. The upper church, that was taken into account in this study, has a *quincuncial* plan (Fig. 1), inscribed in a 12 m square. An iconostasis made of wood and having three openings divides the interior space into the sanctuary, exclusively used by the clergy, covering an area of about 50 m^2, and the area for the congregation (about 100 m^2). The dome reaches a maximum height of 19.3 m. Barrel vaults cover the four braces of the cross, while angular bays are covered by cross-vaults. Walls and vaults are finished in plaster, while the floor is made of smooth limestone but about one third of its surface (most of the sanctuary area) is covered by carpets (Fig. S1 online). Several pieces of wooden furniture can be found in the church. The total volume of the church is slightly less than 1500 m^3.

3.2. Measurement method

Acoustic measurements were carried out under unoccupied conditions according to specific standards [9] and guidelines [3]. A dodecahedron sound source with a frequency response from 100 Hz to 10 kHz was fed by a 9 s logarithmic sine sweep. The sound was recorded using an Eigenmike 32 microphone array, controlled through a software that hosts a VST-plugin to perform beamforming, also allowing Ambisonic decomposition. The 32 channel response was first processed in Matlab to get the impulse responses (IRs), and then the resulting signals were processed again using the VST-plugin to get the desired 3D decomposition (in this case the four B-format components).

Considering the directivity limits pointed out for dodecahedron sound sources [10] and the reduced source-receiver distance which may emphasize the role of direct sound and early reflections, IRs were measured at each receiver by rotating the source to form angles of 0, 30 and 60°. Consequently, ISO 3382 acoustic parameters for each position were calculated by averaging the values resulting from the three rotations. Sound source was located in front and behind the iconostasis, to represent the usual positions of the priest during the celebration. Finally, six receivers were distributed in the congregation area.

4. Results

4.1. Analysis of measured acoustical parameters

The analysis of reverberation time (T30) measurements (Fig. 2) showed an average value at medium frequencies (500 Hz and 1 kHz)